

Performance of Various Types of Diodes at Cryogenic Temperatures

Richard Patterson, NASA Glenn Research Center
 Ahmad Hammoud, QSS Group, Inc. / NASA GRC
 Malik Elbuluk, University of Akron
 Scott Gerber, ZIN Technologies / NASA GRC

Scope

Electronic circuits in certain space missions are exposed to very low temperatures. Very limited data exist on the performance and reliability of electronic devices and circuits at cryogenic temperatures below the manufacturer's specified operating temperature range. This report summarizes the preliminary results obtained on the evaluation of six types of diodes at low temperatures. This database can be used as a design tool for screening and identifying diodes with potential use in extreme temperature applications.

Test Procedure

Several types of diodes from various manufacturers were selected for evaluation at cryogenic temperatures. These included small signal, zener, and Schottky diodes. Two devices of each type of diode were examined for operation between -190 °C and +25 °C. Performance characterization was obtained in terms of their forward voltage-current characteristics, using a Sony/Tektronix 370A programmable curve tracer, at specific test temperatures. Cold-restart capability, i.e. power switched on while the devices were at a temperature of -190 °C, was also investigated. A temperature rate of change of 10 °C per minute was used, and a soak time of at least 20 minutes was allowed at every test temperature. Table I shows some of the manufacturer's specifications for these devices [1-6].

Table I. Manufacturer's specifications of diodes [1-6].

Parameter, Symbol (Unit)	1N4148 Small Signal	MUR420 High Current	1N4005 High Current	1N759A Zener	SR104 Schottky	1N5819 Schottky
Average Forward Current, $I_{F(AV)}$ (A)	0.2	4.0	1.0	0.038	1.0	1.0
Non-repetitive Forward Current, I_{FSM} (A)	1 - 4	150	30	-	40	25
Forward Voltage, V_F (V)	0.6 – 1.0	0.71 – 0.89	1.1	12	0.55	0.6 – 0.9
Max. Repetitive Rev. Voltage, V_{RRM} (V)	100	200	600	-	40	40
Power Dissipation, P_D (W)	0.5	-	3.0	0.5	-	1.25
Operating Temperature, T_J (°C)	-65 to +175	-65 to +175	-55 to +175	-65 to +175	-55 to +125	-65 to +125
Packaging	DO-35 Hermetic Glass	DO-201AD Plastic	DO-41 Plastic	DO-35 Hermetic Glass	DO-41 Plastic	DO-41 Plastic
Manufacturer	Fairchild	Vishay	Fairchild	Fairchild	MEI	Fairchild

Test Results

Although two devices of each of the six different diodes were evaluated, data pertaining to only one of each type of these devices is presented due to the similarity in the results of the same type devices.

Temperature Effects

The forward voltage-current characteristics of the diodes were obtained at test temperatures of 20, -50, -75, -100, -125, -150, -175, and -195 °C. All diodes exhibited similar temperature dependency as they all underwent a gradual increase in forward voltage as test temperature was decreased. The magnitude of this forward voltage varied from one type of diode to another. The voltage-current characteristics of 1N4148, MUR420, 1N4005, 1N759A, SR104 and 1N5819 diode are shown in Figures 1-6, respectively. For simplicity, only the data obtained at the two extreme temperatures, i.e. +25 and -190 °C, are shown in these figures. It can be seen that the three rectifying diodes; namely 1N4148, MUR420, and 1N4005, displayed almost exact trend in their voltage-current characteristics with temperature. Similarly, the two types of Schottky diodes tested exhibited the same behavior in their characteristics with temperature. In addition to an increase in their forward voltage with decrease in temperature, all diodes exhibited a slight reduction in their on-resistance at low temperatures, as reflected by the steepness of the voltage-current curves at -195 °C.

Cold Re-Start

Cold-restart capability of the six types of diodes was investigated by allowing the devices to soak at -190 °C for 20 minutes without electrical bias. Power was then applied to the device under test, and measurements were taken on the forward voltage-current characteristics. All diodes did perform cold start at -190 °C, and the results obtained were similar to those obtained earlier at that temperature.

Conclusions

Six types of different diodes were evaluated for operation between -190 °C and +20 °C. These devices included three general purpose, ultra fast rectifiers, one zener, and two Schottky diodes. Cold-restart capability at -190 °C was also investigated. All diodes were able to maintain operation between -190 °C and +20 °C. The temperature-induced changes included an increase in forward voltage and a slight reduction in the on-resistance at cryogenic temperatures. In addition, all the diodes were able to cold start at -190 °C. Further testing under long term cycling is, however, required to fully establish the reliability of these devices and to determine their suitability for extended use in extreme temperature environments.

References

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- [3]. Fairchild Semiconductor Corporation, “1N4001 - 1N4007 General Purpose Rectifiers Data Sheet”, Rev.C1, 2003.
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- [6]. Fairchild Semiconductor Corporation, “1N5819 Schottky Rectifier Data Sheet”, Rev. C, 2001.

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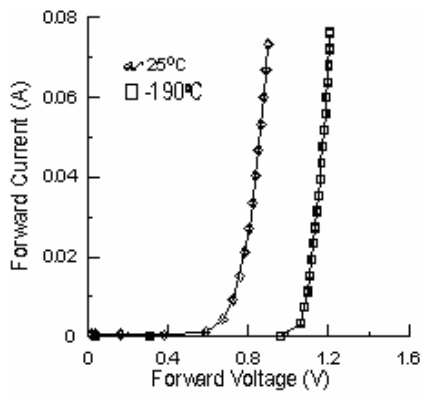


Fig 1. V/I characteristics of 1N4148 small signal diode.

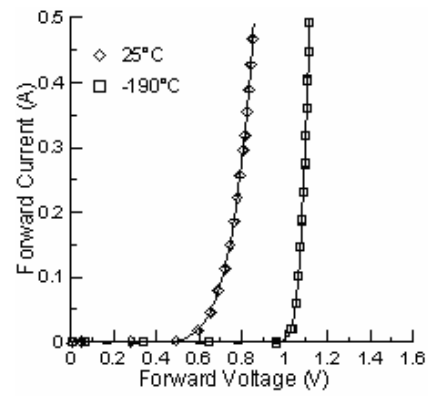


Fig 2. V/I characteristics of MUR420 high current diode.

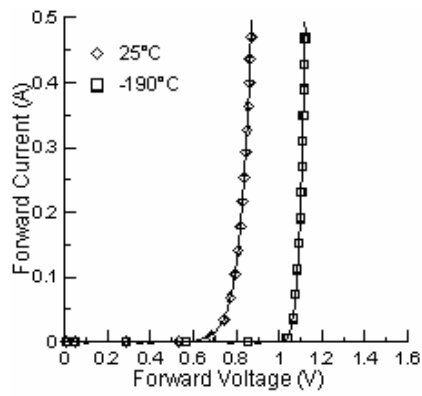


Fig 3. V/I characteristics of 1N4005 high current diode.

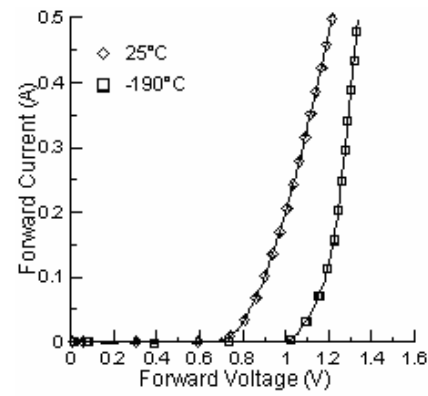


Fig 4. V/I characteristics of 1N759A zener diode.

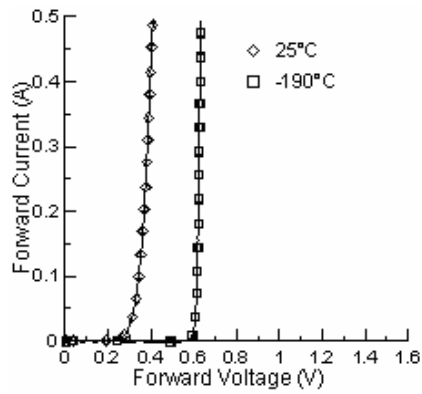


Fig 5. V/I characteristics of SR104 Schottky diode.

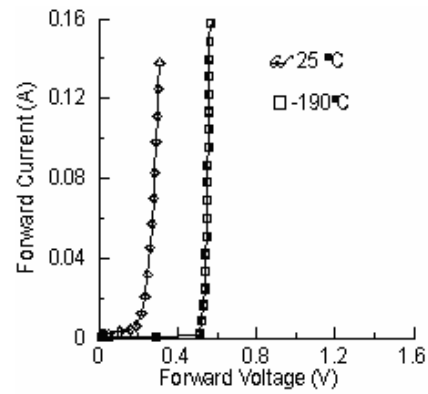


Fig 6. V/I characteristics of 1N5819 Schottky diode.

Forward voltage-current characteristics of 1N4148 diode as a function of temperature